Technological solutions to reduce the geometrical defects during the cast film process

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Abstract
The polymer cast film process induces some geometrical defects : the width reduction (neck-in defect) and the inhomogeneous decrease of the thickness distribution (edge bead defect). These defects prevent from predicting the film final dimensions and thus from a high industrial productivity.
In this paper, a numerical model developed by the authors is used to test and optimize two technological solutions, aimed at reducing the geometrical defects : a localized air cooling on the edges of the film at the die exit and an "encapsulation die" which enables the extrusion of a high melt strength polymer along the outer edge of a core polymer. Numerical results are confronted with experimental investigations.

1 Introduction

Cast film process is widely used to produce polymer film : a molten polymer is extruded through a flat die, then stretched in air and finally cooled down on a chill roll. During the path in air, while the polymer cools, the film shows a lateral neck-in as well as an inhomogeneous decrease of the thickness leading to edge beads surrounding a central area of constant thickness ("dog bone" defect).
These geometrical defects are very constraining and technological solutions were proposed to reduce them. In this paper, two technological solutions are investigated. The first one consists in cooling the web on the film edges at the die exit. This cooling, for example thanks to lateral air jets, creates edge strips of more viscous polymer, reducing thus the neck-in phenomenon. Although this solution has been evoked by two authors (1, 2) to improve PET cast film, no experimental nor numerical investigations of the effect of this cooling on the film geometry exist.
The second technological solution consists in extruding a high melt strength polymer along the outer edge of a less viscous core polymer. This requires the use of a special die called an "encapsulation die". Debbaut et al. (3) have made a rather complete experimental investigation of this "encapsulation" technology, but no numerical investigation has been proposed.
A 2D non isothermal model, both Newtonian and viscoelastic, enabling to predict accurately the final film dimensions, developed by Sollogoub et al. (4, 5), was used to test the effect on the film geometry of the two technological solutions presented above.

2 Results and confrontation with experimental results

2.1 Lateral air cooling

The effect of a lateral air cooling is taken into account in the model through a heterogeneous heat transfer coefficient, with higher values at the edge of the extrudate at die exit. Figure 1 compares the computed final thickness profile with and without lateral air cooling. It appears that the neck-in defect is strongly reduced by this lateral cooling. The confrontation of the experimental and computed thickness profiles, obtained with the air lateral cooling, shows a good agreement and the ability of the model to test this new technological solution.

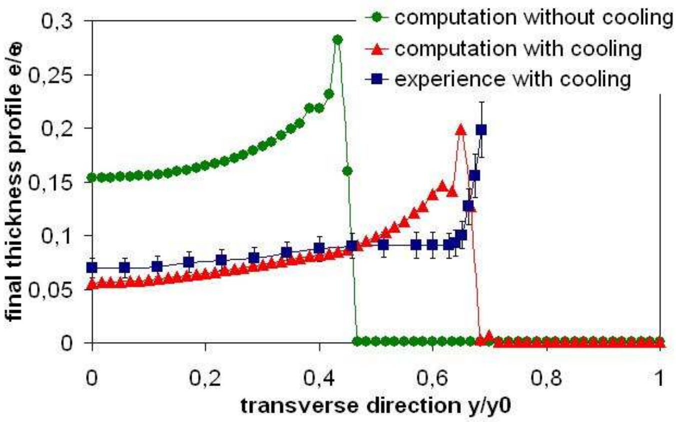

Figure 1: Experimental and computed final thickness profiles with and without the air lateral cooling

2.2 The encapsulation

The V.O.F method, used in the 2D model, allows to distinguish the polymer area from the fictitious fluid surrounding it by the means of a characteristic function which equals 1 in the polymer domain and 0 elsewhere. For the “encapsulation method”, we consider three subdomains : the core polymer, the polymer at the edge and finally the fictitious domain, and two characteristic functions, one for each polymer, are computed in the domain.
Two different rheological behaviours (viscosity and relaxation time) are considered for the two polymers. In figure 2, the core polymer is Newtonian whereas the edge polymer is viscoelastic. The final thickness profile of the core polymer appears to be more uniform when using an encapsulation technology.

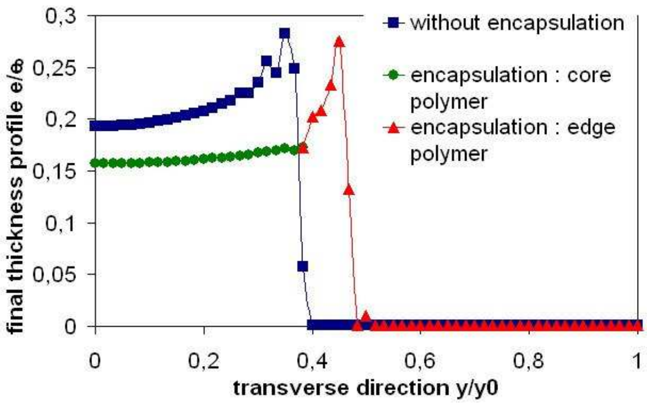

Figure 2: The encapsulation method and the computation of the two characteristic functions

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